

The Effect of Heating of B20 Fuel to Combustion Characteristic on the Diesel Engine Based on Experiment

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Abstract – according to Bank Indonesia, the current account deficit of Indonesia. In the second quarter of 2018 increased to USD 8.0 billion. One of the government's programs to reduce the current account deficit is by implementing a B20 biodiesel policy. The increasing percentage of biodiesel in fuel blends tends to decrease the quality of spray atomization, where it indicated by longer droplet breakup, spray penetration, droplet lifetime, and bigger droplet diameter. Higher viscosity causes a decrease in the quality of the spray from the injector. Previous research shows that the inlet temperature of the fuel can make the performance of small diesel engines slightly better. The research was conducted using petrodiesel and biodiesel fuel by varying inlet temperature of 50°C and 70°C. Based on that this research is conducted to understand the effect of fuel heating diesel engine combustion process. The result shows that generally maximum pressure is increased for every increase in fuel temperature. The heat release shows a decreasing trend for every increase in fuel temperature. Knock detection shows that generally when the fuel temperature increased the knocking is also increased. The increasing fuel temperature shows little effect on ignition delay except for the higher temperature of 60°C and 70°C where the ignition delay is the lowest and closest to that of a dextrite fuel.

Keywords—B20, biodiesel combustion process, fuel heating.

I. INTRODUCTION

According to Bank Indonesia, the current account deficit of Indonesia. In the second quarter of 2018 increased to USD 8.0 billion. One of the government's programs to reduce the current account deficit is by implementing a B20 biodiesel policy. This policy is expected to reduce oil imports and can save the national budget for imports, thus reducing the current account deficit. The policy officially replaces the pure diesel fuel (B0) with Bio Solar (B20) since September 1st, 2018 through ministerial decree 1936 K / 10 / MEM / 2018 about the procurement of biodiesel fuel starting from September 2018 [1].

Indonesia is the biggest producer of Crude Palm oil in the world, has a very good opportunity to produce biodiesel. Besides crude palm oil, there are some resources that can be used as a source of biodiesel like *Jatropha* with 557,842,000 barrels per year, algae with 258,867,000 barrels per year and some other resources. It is predicted that with these supplies Indonesia can withstand the energy crisis up to 2101 [2]. Biodiesel fuel is already used as B20 fuel for general use for diesel

engines from transportation to production. Starting from September 1st 2018, by ministerial decree 1936 K / 10 / MEM / 2018 about the procurement of biodiesel fuel from September, Indonesia started to effectively be commercialized the B20 fuel through several companies as producer and suppliers. This is done to reduce diesel fuel import budget for Indonesia.

Biodiesel fuel has advantages compared to diesel fuel. According to [3] these advantages are made from renewable sources, better emissions, and better lubricating property. The disadvantage of Biodiesel is more expensive than fossil fuel, less suitable for low temperatures, and has a higher viscosity than pure diesel fuel.

Biodiesel is chemically referred to as methyl ester or ethyl ester of fatty acids produced from plant vegetable oils or animal oils. Biodiesel derived from vegetable oil is made by converting triglycerides into fatty acids, using the catalyst in the esterification process. Biodiesel has the same physical and chemical properties as conventional diesel fuel. In general, biodiesel has an energy content that is almost close to diesel fuel. So it can be used to power engines for transportation and for agricultural purposes.

There are several factors like ignition delay, knocking, Rate of heat release, and pressure affecting the combustion process of the combustion chamber. Each of these factors is caused by different variables whether it's the fuel calorific value, fuel cetane number, fuel spray pattern, injection timing etc. All of those factors can affect the performance of the engine.

II. METHOD

A. Ignition Delay

Theoretically the combustion process in a diesel engine starts when the piston compresses the air in the combustion chamber, then when the piston reaches the

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Top Dead center, the fuel is injected which will burn by itself because the temperature of the combustion chamber has reached the flashpoint of the fuel. In fact there is a delay since the start of fuel injection with the occurrence of combustion. This delay is called Ignition delay [4].

The main reason for ignition delay depends on the cetane number (CN) of the fuel used. Cetane number is a number that provides a measure of ignition characteristics of diesel fuel when it is burnt in the diesel engines. The fuel which has a lower cetane number has longer ignition delay characteristics [5].

B. Maximum Pressure

One of the factors of the combustion process is the pressure produced by the combustion. In the diesel engines, the peak pressure of the combustion chamber depends on the fraction of fuel burned during the premixed burning phase, i.e initial stage of combustion. The pressure of the cylinder characterizes the ability of the fuel to mix well in the air and burn [6].

C. Rate of Heat Release

The rate of heat release is defined as the heat released from a chemical in a given time. By knowing the heat release rate parameter, some of the combustion phenomena in the engine cylinder can be analyzed. Phenomena parameters such as combustion duration and intensity can be easily estimated from the heat release rate diagram [7]. The heat release rate and the diagram is

shown in figure 1 and figure 2.

D. Knocking

Sometimes Diesel engines can experience abrupt cylinder pressure rise due to the rapid increase of fuel combustion rate. This is sometimes because of the fuel has longer ignition delay, the burning of the first droplets is longer, and more fuel is accumulated in the combustion chamber. Then when the ignition occurs, it burns violently and creates pressure oscillations. This phenomenon is called knocking [8].

There are several ways to improve engine performance. It is proven that by increasing the injection pressure there is an increase in engine power because of better combustion [9]. The second way to improve this is to add the number of nozzle holes for better spray distribution and improving the hole geometry of the nozzle. This way it is computationally proved that more nozzle hole and improved hole geometry have a better effect on the performance of a diesel engine [10]. This concept is also proven to be good on CNG marine Engines [11].

According to research conducted by [12]. In the research the fuel used was diesel fuel (B0) and up to Biodiesel (B100). In the research the combustion characteristic of both fuels was also analyzed. The result, was quite significant, by using Biodiesel (B100) the ignition delay is increased by 4 degrees and the total heat release is decreased until 26% compared to pure diesel fuel.

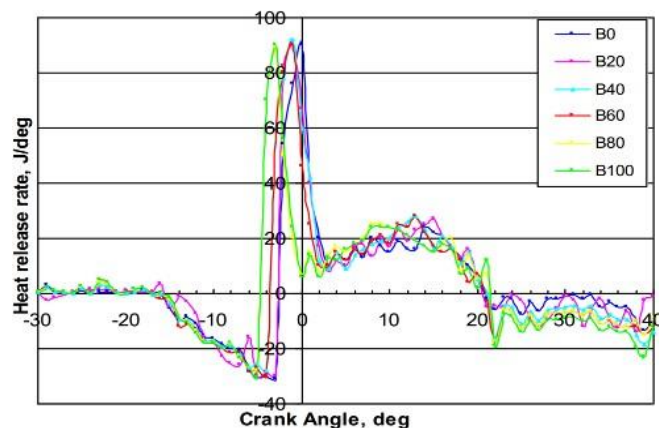


Figure. 1. Heat Release Rate Diagram diagram in the research [12]

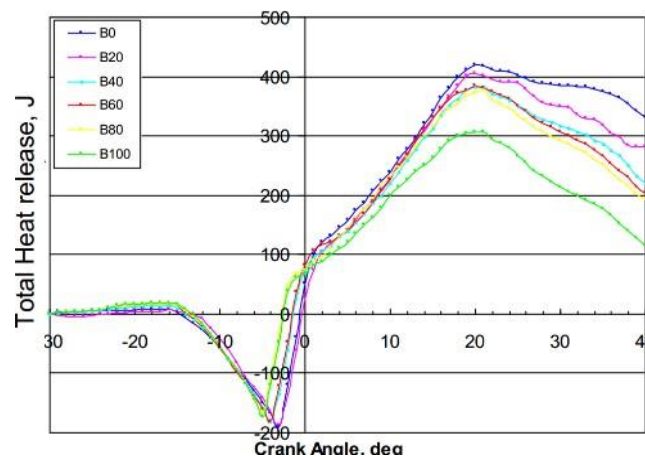


Figure. 2. Heat Release Diagram in the research [12]

Research conducted by [13] proves that the inlet temperature of the fuel can make the performance of small diesel engine slightly better. The research was conducted using petrodiesel and biodiesel fuel by varying inlet temperature of 50°C and 70°C and observing the effect on engine brake thermal efficiency and brake specific fuel consumption.

The research shows that the effect of fuel temperature on brake thermal efficiency of the biodiesel at inlet temperature of ambient temperature, 50°C and 70°C. It is shown that there is an increase of brake thermal efficiency as shown in the figure 3.

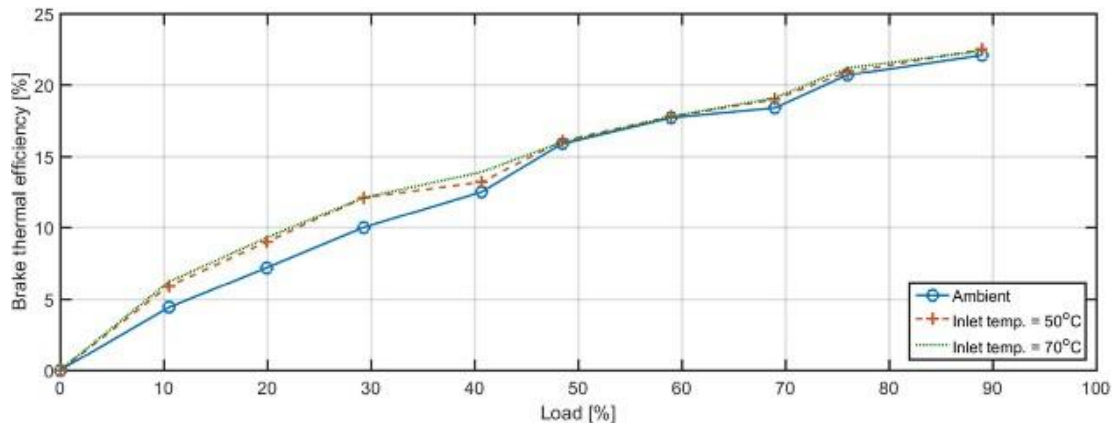


Figure. 3. Brake Thermal Efficiency vs load Graph [13].

The increase of Brake Thermal Efficiency is due to the weakening fuel chain hence better combustion can be achieved. With better combustion, it is expected that the performance of the engine is increased. On Brake

Specific Fuel Consumption (BSFC), there is a slight reduction of BSFC in both petrodiesel and Biodiesel at inlet temperature 70°C as shown in the figure 4.

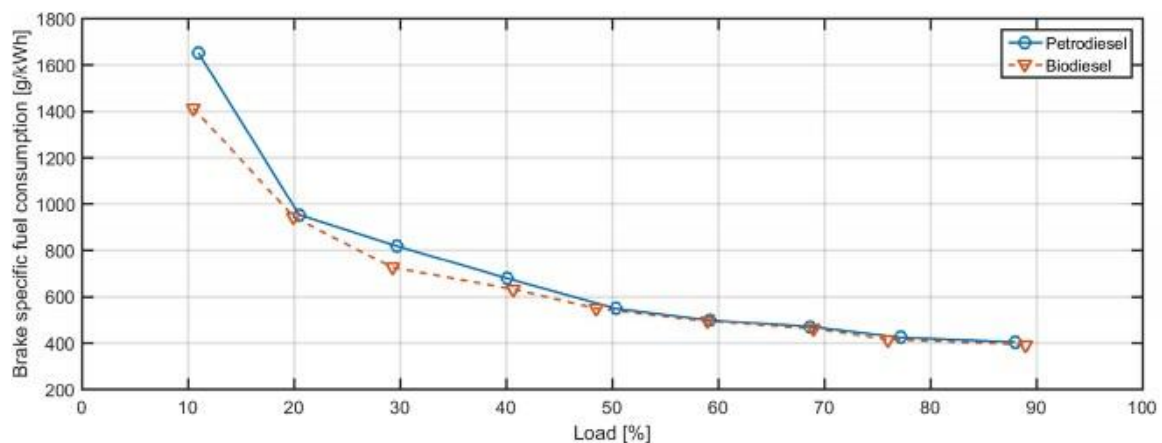


Figure. 4. Brake Specific Fuel Consumption vs Load [13].

Based on the research conducted by [12,13] a further research needs to be conducted to seek the best inlet fuel temperature based on performance, spray characteristic and combustion characteristics. The research is also to be made with bigger diesel engine compared to the research

done by [13] in order to see how much the effect of fuel preheating will take place. The effect of preheating can also be seen by doing combustion characteristic test on preheated fuel.

III. RESULT AND DISCUSSIONS

The engine ran at 1800 RPM and 2000 RPM with 100% load. The fuel heating is done by using a heat exchanger installed as a bypass on the engine cooling system. Fuel temperature is controlled by a solenoid valve which is controlled by a thermostat. The valve is located on the water intake of the heat exchanger.

The engine will be attached to a rotating encoder and pressure transducer which will be connected to

combustion analyzer. The data from combustion analyzer is taken from the prechamber/swirl-chamber of the engine. Analysis of combustion process is using TMRInstrument sensor and SYSMONSoft as data acquisition. Setup experiment can be seen in figure 5 and figure 6.

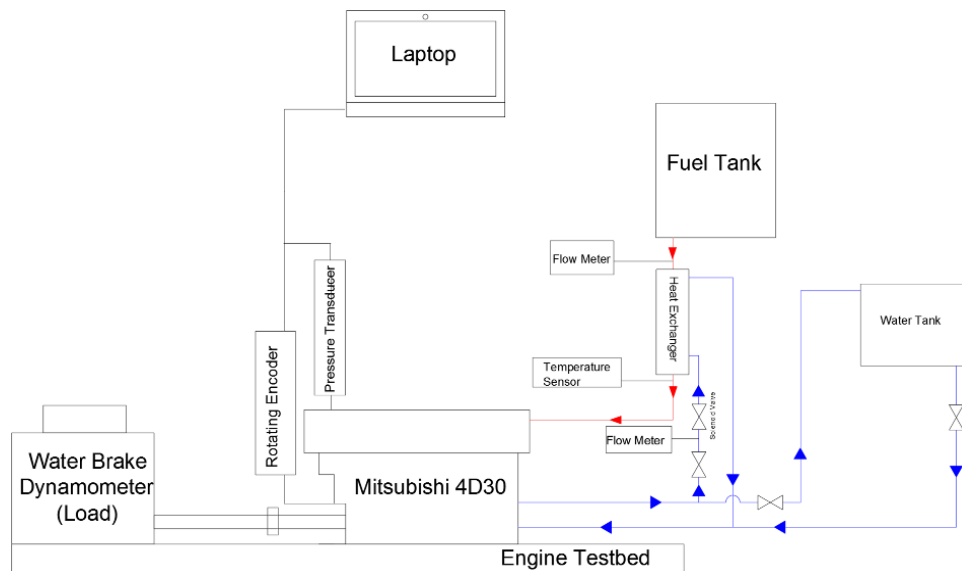


Figure 5. Combustion characteristic test schematic setup.



Figure 6. Combustion characteristic test setup.

The fuel used in this experiment is B20 named “bio solar” which has widely used in Indonesia and as for

comparison, B0 fuel is used named “dexlite”. The specification for B20 is shown in table 1.

TABLE 1.
SPECIFICATION OF B20 “BIOSOLAR”

No	Characteristic	Units	Limits	
			Minimum	Maximum
1	Cetane Number	-	48	-
	Cetane Index	-	45	-
2	Density @ 15°C	Kg/m ³	815	860
3	Viscosity @ 40°C	mm ³ /sec	2.0	4.5
4	Sulphur Content	%m/m	-	0.25
5	Distillation 90% evaporation	°C	-	370
6	Flash Point	°C	52	-
7	Pour Point	°C	-	18
8	Carbon Residue	%m/m	-	0.1
9	Water Content	mg/kg	-	500
10	Biological Growth	-	-	-
11	FAME Content	% v/v	-	-
12	Methanol Content	% v/v	-	-
13	Ash Content	% v/v	-	0.01
14	Sediment Content	% m/m	-	0.01
15	Strong Acid Number	mgKOH/gr	-	0
16	Total Acid Number	mgKOH/gr	-	0.6
17	Particulate	mg/l	-	-
18	Visual Appearance	-	Bright and clear	
19	Color	No.ASTM	-	30
20	Lubricity	micron	-	460

The Engine that is used in the research is Mitsubishi 4D30. The engine specification is mentioned in table 2.

TABLE 2.
ENGINE SPECIFICATION

No.	Description	Parameter	Unit
1	Manufacturer	Mitsubishi	
2	Model	4D30	
3	Type	Inline 4, Water Cooled, 4-stroke Diesel Engine	
4	Valve Mechanism	Over Head Valve	
5	Type of combustion chamber	Swirl Chamber	
6	Bore x Stroke	100 x 105	mm
7	Displacement	3298	cc
8	Max Power	90	PS
9	Max Torque	22 @1800 RPM	kgfm
10	Fuel Injection Pressure	120	Kg/cm ²
11	Injection Timing	14°	BTDC

A. Maximum Pressure

Figure 7 showing the maximum Pressure graph analysis at 1800 RPM for B20 fuel with fuel variation and dextlite as comparison. It can be observed that B20 fuel at 30°C can achieve 41.71 bar of maximum pressure at 7° angle after TDC. Then B20 at 40°C can achieve

42.34 bar of maximum pressure at 7° angle after TDC. For B20 at 50°C can achieve 41.96 bar of maximum pressure at 8° angle after TDC. B20 at 60°C can achieve 43.09 bar of maximum pressure at 8° angle after TDC.

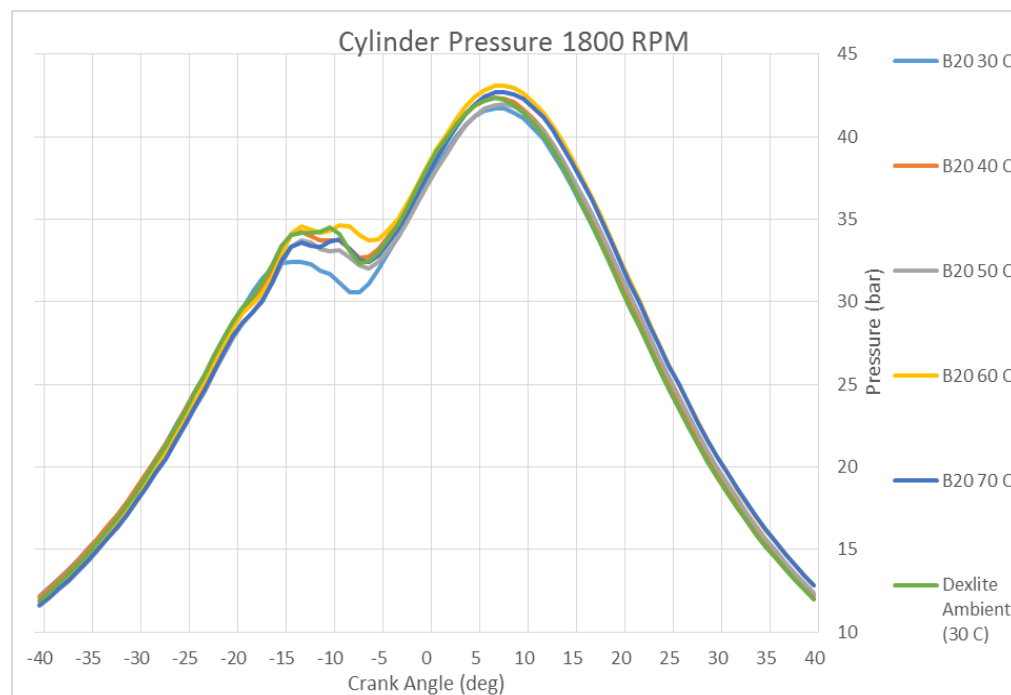


Figure. 7. Maximum Pressure Graph.

Then B20 at 70°C can achieve 42.71 bar of maximum pressure at 8° angle after TDC. As for comparison dextlite can achieve 42.33 bar of maximum pressure at 7° angle after TDC. The value of Maximum Pressure and

the angle it's achieve is depending on how long the fuel burnt and the ignition delay time. The longer the ignition delay time means the topmost point will be having more distance from the injection point at 14° before TDC.

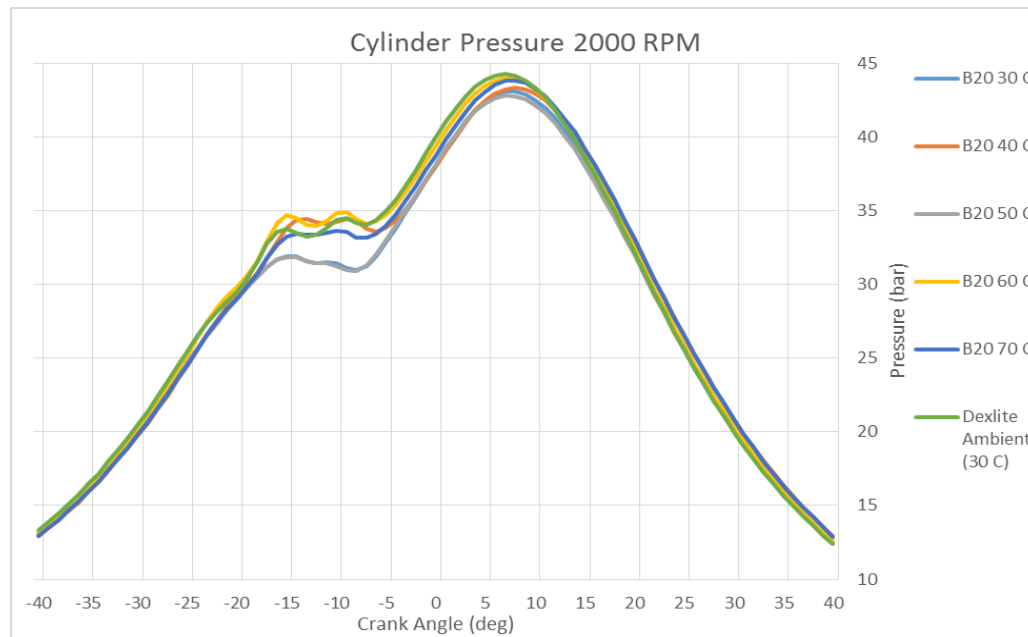


Figure. 8. Maximum Pressure Graph.

Figure 8 is showing the max Pressure graph analysis at 2000 RPM for B20 fuel with fuel variation and dexlite as comparison. It can be observed that B20 fuel at 30°C can achieve 43.07 bar of maximum pressure at 8° angle after TDC. Then B20 at 40°C can achieve 43.30 bar of maximum pressure at 8° angle after TDC. For B20 at 50°C can achieve 42.81 bar of maximum pressure at 7° angle after TDC. B20 at 60°C can achieve 44.0 bar of maximum pressure at 7° angle after TDC. Then B20 at 70°C can achieve 43.82 bar of maximum pressure at 8°

angle after TDC. As for comparison dexlite can achieve 44.30 bar of maximum pressure at 7° angle after TDC. The value of Maximum Pressure and the angle it's achieve is depending on how long the fuel burnt and the ignition delay time. The longer the ignition delay time means the topmost point will be having more distance from the injection point at 14° before TDC.

B. Rate of Heat Release

From Figure 9 the result can be known. From Rate of heat release graph ignition delay can be known. The injection timing for Mitsubishi 4D30 is 14° before TDC. It then can be observed that B20 at 30°C has earliest combustion at 2° before TDC and has highest heat release at 11° after TDC with the value of 27.05

$\text{kJ/m}^3/\text{deg}$. Then B20 at 40°C has earliest combustion at 2° before TDC and has highest heat release at 10° after TDC with the value of 20.84 $\text{kJ/m}^3/\text{deg}$. Then B20 at 50°C has earliest combustion at 3° before TDC and has highest heat release at 11° after TDC with the value of 25.21 $\text{kJ/m}^3/\text{deg}$.

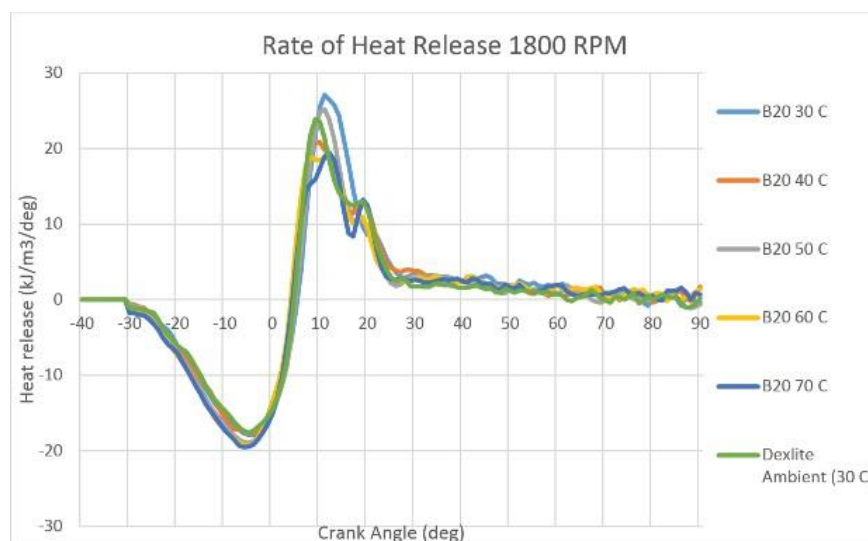


Figure. 9. Rate of Heat release Graph.

Then B20 at 60°C has earliest combustion at 3° before TDC and has highest heat release at 8° after TDC with

the value of 18.9 $\text{kJ/m}^3/\text{deg}$. Then B20 at 70°C has earliest combustion at 3° before TDC and has highest

heat release at 12° after TDC with the value of 19.46 kJ/m³/deg. Then Dexlite for comparison has earliest

combustion at 4° before TDC and has highest heat release at 9° after TDC with the value of 23.9 kJ/m³/deg.

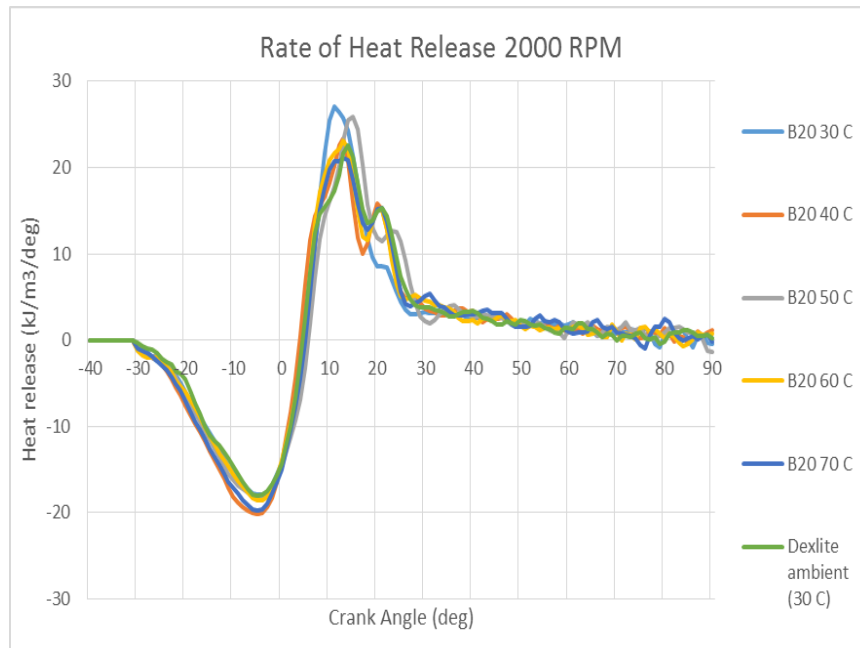


Figure. 10. Rate of Heat release Graph.

From the Figure 10 the result can be known. From Rate of heat release graph ignition delay can be known. The injection timing for Mitsubishi 4D30 is 14° before TDC. It then can be observed that B20 at 30°C has earliest combustion at 3° before TDC and has highest heat release at 11° after TDC with the value of 27.41 kJ/m³/deg. Then B20 at 40°C has earliest combustion at 2° before TDC and has highest heat release at 13° after TDC with the value of 23.35 kJ/m³/deg. Then B20 at 50°C has earliest combustion at 1° before TDC and has highest heat release at 15° after TDC with the value of

25.95 kJ/m³/deg. Then B20 at 60°C has earliest combustion at 3° before TDC and has highest heat release at 13° after TDC with the value of 23.1 kJ/m³/deg. Then B20 at 70°C has earliest combustion at 4° before TDC and has highest heat release at 15° after TDC with the value of 25.16 kJ/m³/deg. Then Dexlite for comparison has earliest combustion at 4° before TDC and has highest heat release at 14° after TDC with the value of 22.62 kJ/m³/deg.

C. Knock Detection

Figure 11 is the knock Detection graph analysis at 1800 RPM. The graph shown the knock detection for B20 inlet temperature ranging from 30°C to 70°C and Dexlite for comparison. B20 fuel at 30°C has highest

point of knocking at 0.82 at 7° after TDC. B20 fuel at 40°C has highest point of knocking at 0.96 at 14° after TDC.

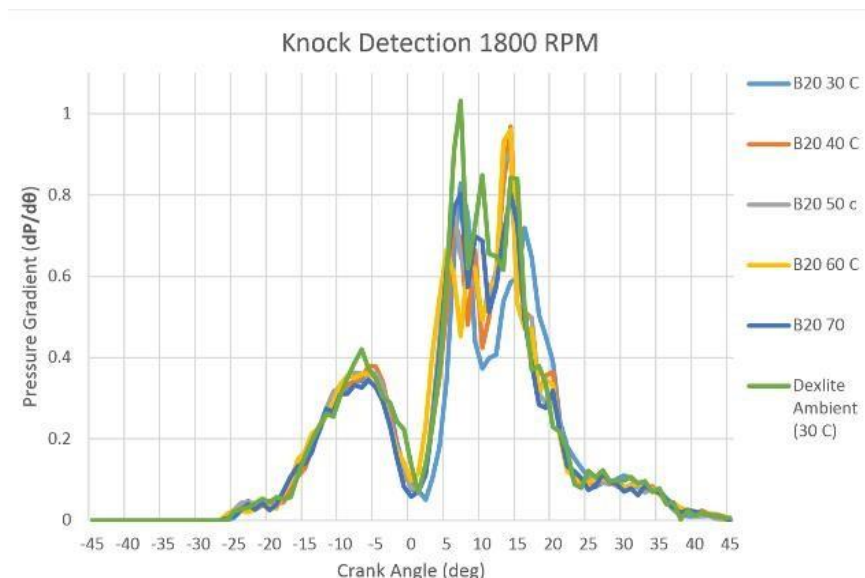


Figure. 11. Knock Detection Graph.

The B20 fuel at 50°C has highest point of knocking at 0.90 at 14° after TDC. B20 fuel at 60°C has highest point of knocking at 0.96 at 14° after TDC. B20 fuel at 70°C

has highest point of knocking at 0.80 at 14° after TDC. Dexlite for comparison has highest point of knocking at 1.03 at 7° after TDC.

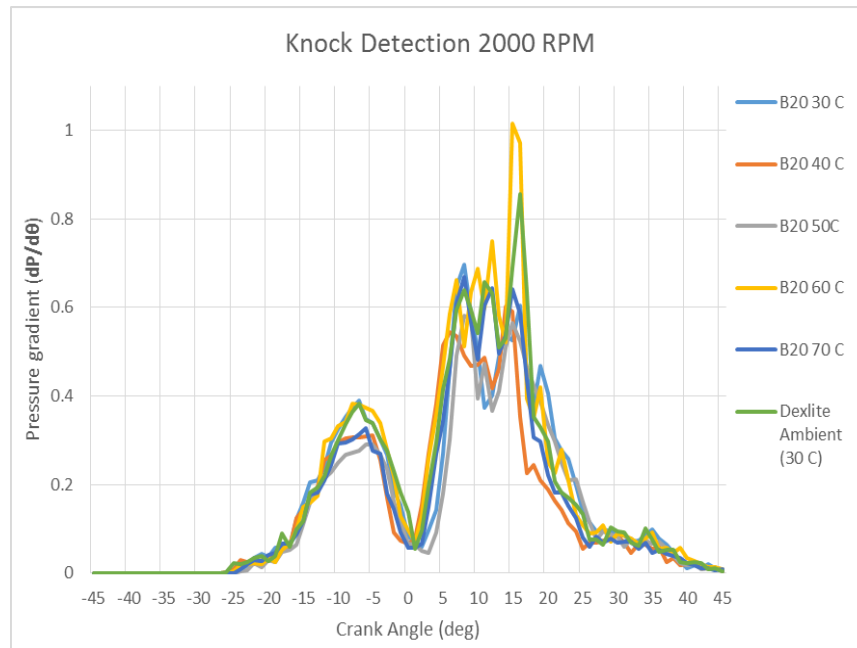


Figure. 12. Knock Detection Graph.

Figure 12 is the knock Detection graph analysis at 2000 RPM. The graph shown the knock detection for B20 inlet temperature ranging from 30°C to 70°C and Dexlite for comparison. B20 fuel at 30°C has highest point of knocking at 0.69 at 8° after TDC. B20 fuel at 40°C has highest point of knocking at 0.60 at 14° after TDC. B20 fuel at 50°C has highest point of knocking at

0.58 at 8° after TDC. B20 fuel at 60°C has highest point of knocking at 1.01 at 15° after TDC. B20 fuel at 70°C has highest point of knocking at 0.66 at 8° after TDC. Dexlite for comparison has highest point of knocking at 0.85 at 16° after TDC.

D. Ignition Delay

Figure 13 is showing the ignition delay of B20 fuel for every inlet temperature. The ignition delay for B20 at 30°C inlet temperature is 1.111 ms. Ignition delay for B20 at 40°C inlet temperature is 1.111 ms. Ignition delay for B20 at 50°C inlet temperature is 1.018 ms. Ignition

delay for B20 at 60°C inlet temperature is 1.018 ms. Ignition delay for B20 at 70°C inlet temperature is 1.018 ms. While Dexlite achieve the lowest ignition delay at 0.925 ms.

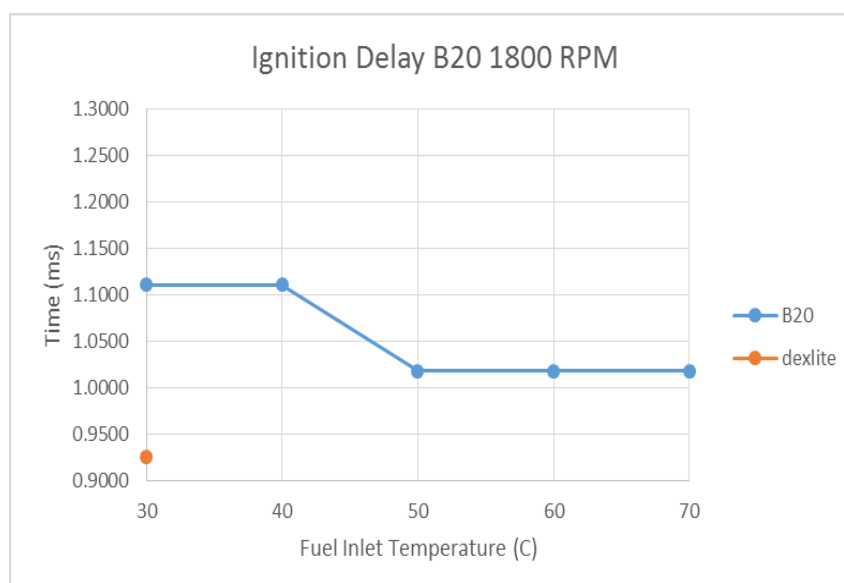


Figure. 13. Ignition Delay Graph.

Ignition delay time depends on the value of cetane number of the fuel. The higher the cetane number of a fuel, the faster the time takes for the fuel to ignite. Therefore higher cetane number means shorter ignition

delay. In this case Dexlite has shorter ignition delay. This is due to the fact that Dexlite has cetane number of 51. While B20 (Biosolar) has cetane number of 48.

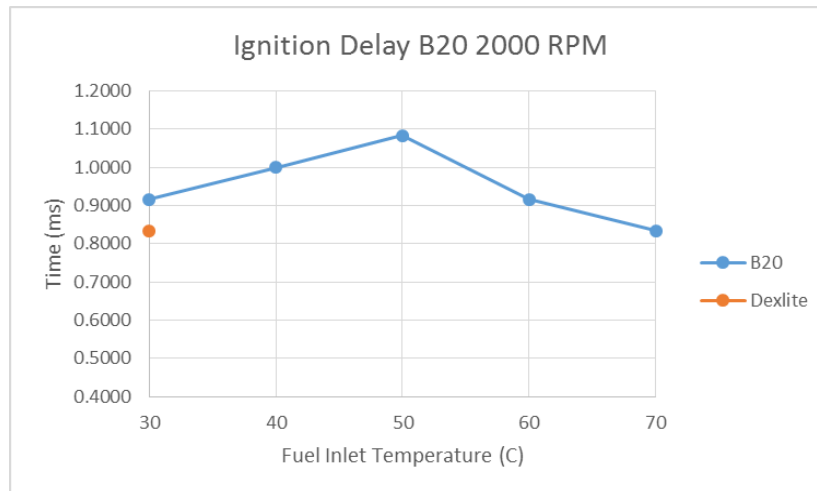


Figure. 14. Ignition Delay Graph.

Figure 14 is showing the ignition delay of B20 fuel for every inlet temperature. The ignition delay for B20 at 30°C inlet temperature is 0.916 ms. Ignition delay for B20 at 40°C inlet temperature is 1 ms. Ignition delay for B20 at 50°C inlet temperature is 1.083 ms. Ignition delay for B20 at 60°C inlet temperature is 0.916 ms. Ignition delay for B20 at 70°C inlet temperature is 0.833 ms. While Dexlite achieve the lowest ignition delay at 0.833 ms.

Ignition delay time depends on the value of cetane number of the fuel. the higher the cetane number of a fuel, the faster the time takes for the fuel to ignite. Therefore higher cetane number means shorter ignition delay. In this case Dexlite has shorter ignition delay. This is due to the fact that Dexlite has cetane number of 51. While B20 (Biosolar) has cetane number of 48.

IV. CONCLUSIONS

B20 Temperature can affect the combustion characteristics with detail as follows:

- Based on Maximum pressure graph, it is shown that there is an increasing trend of pressure when the fuel inlet temperature is increased. But the trend goes downward on high temperatures like 60°C and 70°C. The result also shows that there is little effect on the crank angle of highest pressure is achieved. The highest pressure is always achieved at 7 to 8 degrees after TDC.
- Based on Heat Release rate graph, it is shown that there is decreasing trend on the peak value of heat release rate for when the fuel inlet temperature is increased. This is due to the fact that increasing temperature of fuel inlet causing the fuel density to goes down while the plunger of the injection system has the same volume, so the fuel mass per injection goes into the combustion chamber goes down. The result also shows that mostly the crank angle of highest heat release rate is longest when the fuel inlet temperature is 50°C for every RPM.

- Based on Knock Detection Graph, it is shown that the knocking is generally higher when the temperature of the fuel inlet is increased. The crank angle of the highest point of knocking is varied between first peak at 7°-8° Before TDC or 14°-15° after TDC.
- Based on Ignition delay graph, it is shown that the temperature increase only give a slight effect on ignition delay. The closest temperature and condition to approach the value of dexlite is at higher temperatures of 60°C to 70°C.

REFERENCES

- [1] Kementrian ESDM. "Keputusan Menteri Energi Dan Sumber Daya Mineral Republik Indonesia Nomor 1936 K/10/Mem/2018". Kementrian ESDM Republik Indonesia. (2018)
- [2] Kuncahyo, P., Fathallah, A.Z.M., & Semin (2013). JURNAL TEKNIK POMITS vol.2 (1) (2013)
- [3] Viesturs, Dainis and Ligita Melece. "Advantages and Disadvantages of Biofuels: Observations in Latvia". Latvia University of Agriculture (2014)
- [4] Siagian, A., Silaban, M. Jurnal Teknik Mesin Petra. Vol.14 (1). (2013)
- [5] Rabl, S., Davies, T.J., McDougall, A.P., & R.F Cracknell. Proceedings of the Combustion Institute Vol 35 (3). (2014).
- [6] Qi, D. e. Energy Conversion and Management 51, 2985-2992. (2010).
- [7] Tesfa, B. et al. RE&PGJ, Vol.1, No.9. (2011).
- [8] Lasocki, J. Proceedings of the Institute Of Vehicles 5 (109). (2016).
- [9] Bakar, R.A., Semin., Ismail, A.R. American Journal of Applied Sciences 5 (3): 197-202. (2008)
- [10] Bakar, R.A., Semin., Abdul, R., Ismail A. American Journal of Applied Sciences 5 (2): 110-116. (2008)
- [11] Semin., Beny Cahyono., Amiadji., & R.A Bakar. Procedia Earth and Planetary Science 14(14):101-109. (2014)
- [12] Sudarmanta, B., Rachimoellah, M., Winardi, S., Sungkono, D. RSCE 7. (2007).
- [13] Bin-Mahfouz, A., Mahmoud, K., & Mourad, M. AASCIT Vol. 5,(3):42-48. (2018).